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HISTORY OF ESTABLISHMENT, MAIN CHARACTERISTICS AND SCIENTIFIC AND TECHNICAL PROBLEMS OF PRODUCTION OF ROCKET CHARGES AND GUNPOWDERS FOR JET PROJECTS OF THE SOVIET ARMY PERIOD - 1941-1945.

Black powder - the forerunner of modern rocket powder

Considering the issue of creating missile charges for the missiles of the Soviet Army during the Great Patriotic War, one cannot but stop, at least briefly, on the principled assessment of charges for the predecessor missiles.

Numerous historical evidences indicate the presence in the past in the armies of a number of countries of various military missiles and the successful use of many of them, especially widely in the 19th century, in the conduct of hostilities.

However, by the end of the 19th century, not a single army in the world had missile units in its composition. The missiles were removed from service by Austria, England, Russia and other countries.

The immediate reasons for this were the shortcomings of missiles that emerged during their massive use in the 19th century and were common to missiles of any country, namely:

- the danger of destruction when firing missiles of personnel using missiles of troops due to frequent destruction of missiles on launchers and in the active section of the trajectory;
- large dispersion of missiles during firing and, as a result, low efficiency of engaging enemy troops
- insufficient missile firing range and the impossibility of its significant increase.

When considering the device of the missiles, it turned out that with all the variety of design solutions in all missiles, only one type of rocket fuel was used as a source of energy - smoky (or black) powder.

From this gunpowder, which is a mechanical mixture of potassium nitrate, charcoal and sulfur with a ratio of approximately 75:15:10, rocket charges were made by pressing.

The use of black powder for the manufacture of rocket charges in the 19th century was the only technically possible solution and made it possible to create a combat missile weapon that was sufficiently effective for that time. However, black powder, as a rocket fuel, had a number of significant drawbacks, of which we will indicate only a few, namely: the high fragility of black powder rocket charges, a wide variation in the component composition (and, consequently, the ballistic characteristics of the charges), the impossibility of a significant increase in the mass of charges , low energy level.

Based on the foregoing, it should be considered that the disadvantages of jet weapons of the XIX century. to a large, and perhaps to a decisive, degree were due to the limited capabilities of black powder as a rocket fuel.

In barrel artillery in the 19th century. for the manufacture of propellant charges, smoky powder was also used, and the capabilities of barrel and rocket artillery, both in range and in accuracy of fire, were approximately the same. However, the creation at the end of the 19th century. of pyroxylinic powders, which had significantly higher energy characteristics and combustion stability than black powders, was a strong impetus for the development of barrel artillery.

The advent of rifled artillery and the increase in barrel length additionally played a role. As a result, the firing range of artillery shells was significantly increased, and the accuracy of fire was improved. As for jet weapons, no proposals have been made to increase their effectiveness, primarily from the point of view of using new propellants for making rocket charges.

The effectiveness of jet weapons remained unchanged, for more than half a century they disappeared from the arsenals of armies of all countries of the world. Attempts by individual rocketry enthusiasts to create more effective missiles did not go beyond the scope of experimental work and did not give positive results. To overcome the crisis of jet weapons, it was necessary to create a new class of rocket powder, which would be

devoid of the above-mentioned disadvantages of black powder.

The beginning of work in the Soviet Union on the creation of rockets

Rocket charges made of pyroxylinotrotyl powder

In March 1921 in Moscow, as you know, the "Laboratory for the development of inventions of N.I. Tikhomirov" began its activities. In this first Soviet rocket research and development organization, at the very beginning of its work, the possibility of using standard artillery pyroxylin smokeless propellants on a volatile alcohol ether solvent for the manufacture of rocket charges was tested. Experiments carried out in the laboratory of N.I. Tikhomirov, showed the impossibility of using them for this purpose. These propellants, having a thin burning vault and a large initial combustion surface area, burned very quickly, creating an unacceptably high pressure in the rocket chamber. To reduce the pressure, it was necessary to reduce the initial surface of the charge and, provided the total mass of the charge was preserved, to increase the thickness of the arch of the powder element.

However, a significant increase in the thickness of the arch - (over 10 mm) for pyroxylinic propellants, obtained, as is known, with the help of a volatile solvent, was difficult due to the duration of its removal from thick-draft propellants. It was necessary to develop fundamentally new gunpowder suitable for the manufacture of rocket charges.

One of such propellants was pyroxylinotrotyl powder (PTP), created by O. G. Filippov and S. A. Serikov. The PTP formulation used for the manufacture of rocket charges contained 76.5% pyroxylin, 23% TNT and 0.5% centralite. From this gunpowder, it was possible by deaf pressing of a hot mass to prepare thick-walled cylindrical blocks with a central channel, having a dense structure and capable of burning in parallel layers rather stably.

Despite the serious shortcomings of the technological process of obtaining checkers from PTP (low productivity due to the complexity of the technological scheme, a great need for hydraulic presses, the danger of production due to the tendency of the checkers to dust), it was on this pyroxylinotrotyl powder that work was carried out for 10 years to create charges for rocket engines for various purposes, including for aviation rockets.

Rocket charges for aircraft rockets (PC) were the direct predecessors of rocket charges for the main rockets of the Soviet Army during the Great Patriotic War, and therefore we will dwell on their design in more detail.

For one of the aviation rockets, the original 76 mm caliber was installed, which is traditional for Russian artillery.

However, in the manufacture of dies for pressing propellant pellets, the shrinkage of the propellant was inaccurately taken into account, and the actual diameter of the pellets turned out to be 24 mm, which did not ensure the entry of a charge of seven pieces into the chamber of the 76-mm projectile. They did not remake the pressing equipment, but went along the path of increasing the caliber of the projectile.

So, based on the randomly obtained outer diameter of powder bills, taking into account the thickness of the walls of the rocket chamber and the necessary local thickenings along the outer diameter of the engine, the caliber of the aircraft rocket was determined to be 82 mm, and the projectile itself was called PC-82.

The length of the powder checker was also randomly determined, equal to 57.5 mm. According to ballistic calculations, the required charge mass for an 82-mm PC could be obtained with a charge length of 230 mm. Pressing blocks of this length with a central channel using the blind pressing technology turned out to be impossible. I had to reduce the length of each piece by 4 times. The charge turned out to consist of 28 powder bills instead of seven according to the original design (Fig. 1, a).

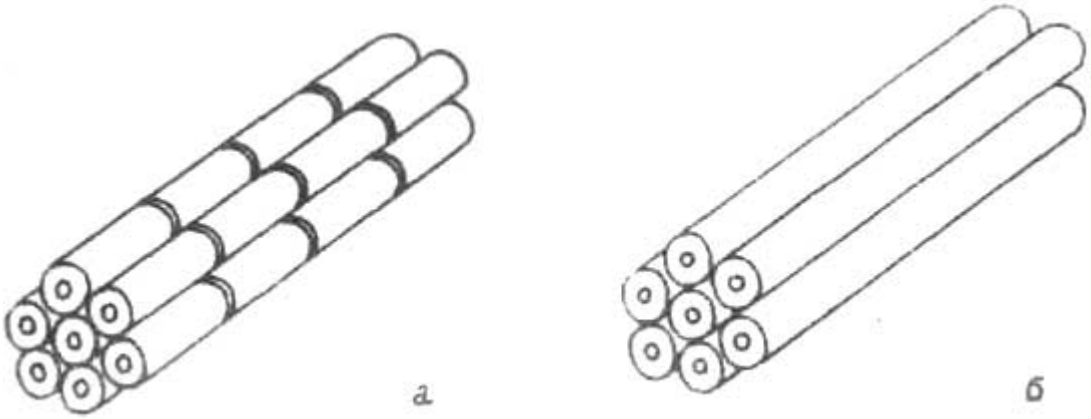

Fig. 1. Rocket charges for aircraft rocket RS-82.
a - until 1939; b - 1939-1945

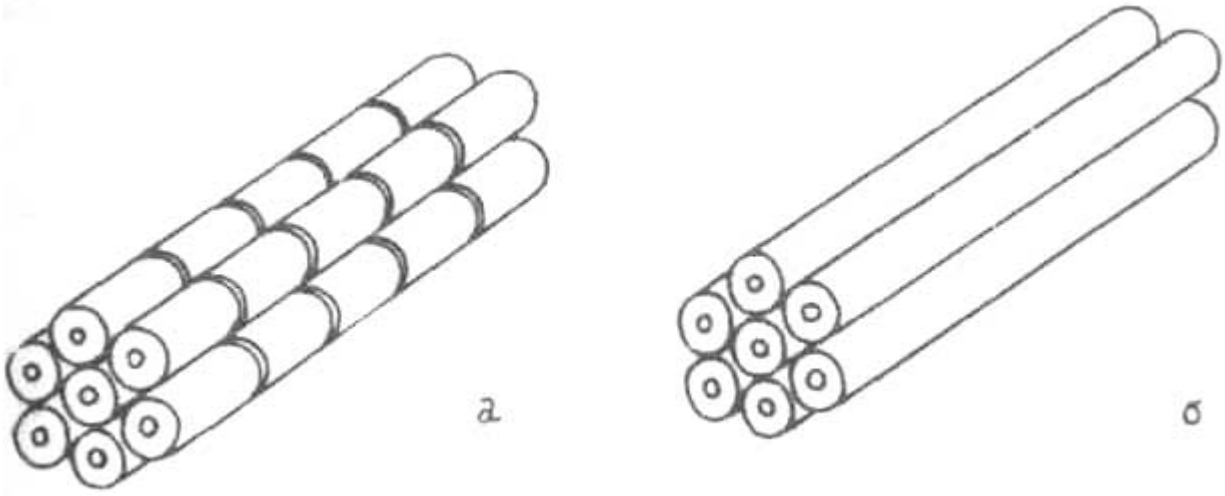

Fig. 2. Rocket charges for aircraft rocket RS-132.
a - until 1939; b - 1939-1945

Note that the diameter of the powder checker, which arose by chance, also determined the caliber of the more powerful PC-132 missile. It happened in this way. To speed up the creation of a larger-caliber rocket, it was decided to use the available 24 mm diameter bombs. Dense stacking of 19 pieces in a row is possible when the inner diameter of the rocket chamber is 122-123 mm, which, taking into account the wall thickness of the rocket chamber and local thickenings, determined the caliber of the rocket projectile - 132 mm. In the future, they worked out the technology of pressing powder bills with an outer diameter of 40 mm and a rope diameter of 8 mm and switched to a rocket charge, which consisted of five rows of such checkers, seven checkers in a row. The charge consisted of 35 such pieces (Fig. 2, a).

Experimental testing of prototypes of aircraft projectiles RS-82 and PC-132 based on the charges of pyroxylinotrotyl powder written off above was completed by the end of 1933, the firing range of these projectiles was 5 and 6 km, respectively. The question arose about their extensive testing, for which it was necessary to supply a large number of rocket charges. However, this could not be ensured by the technology of making pyroxylinotrotyl sticks by deaf pressing. It was not possible to establish continuous pressing of blocks from pyroxylinotrotyl mass. In other words, the anti-tank gun did not meet one of the main requirements for ammunition - the requirement of manufacturability.

The possibility of creating combat missiles in the country during this period became problematic. A crisis situation has arisen. The hulls of the PC-82 and PC-132 aircraft missiles, manufactured for testing in large quantities, could not be used and lay motionless.

Development in the Soviet Union of nitroglycerin ballistic powders for barrel artillery

Regardless of the work carried out at the RNII on the creation of jet weapons, in the Soviet Union under the leadership of A.S. Bakaev, starting from 1924, the development of domestic nitroglycerin powder for barrel artillery was carried out. Since these works, as it turned out later, decisively determined the possibility of creating reactive weapons in the Soviet Union, I will dwell briefly on these developments and their results.

Ballistic propellants consist of compacted nitrocellulose plasticized with nitroglycerin (or other high-energy solvent) without removing the plasticizer solvent. For the first time, ballistic propellants were developed, as is known, in Sweden by A. Nobel and were used for the manufacture of propelling artillery charges in Sweden, Italy and Germany.

Russia, which used pyroxylin powder for all types of artillery weapons, did not have nitroglycerin powder formulations and did not have the industry for their manufacture.

The creation of domestic formulations of nitroglycerin ballistic powders, the technological process of their manufacture, the development of basic principles for the design of factories for the production of nitroglycerin powder, as well as the solution of a number of complex scientific and technical problems that arose during the mass production of rocket charges during the Great Patriotic War are inextricably linked with the name of the Soviet scientist Alexander Semenovich Bakaev. x)

x) Bakaev Alexander Semenovich (1895-1977) - in the twenties, developed scientific and technical principles for the creation of domestic formulations of ballistic nitroglycerin artillery and rocket powders, as well as industrial methods for their production. The use of rocket powders N, NM-2, H-31, etc. developed under his leadership and with direct participation for the manufacture of charges for rockets brought the problem of creating rocket weapons in the country out of the impasse and was one of the decisive prerequisites for widespread deployment during the Great Patriotic War. wars of multiple launch rocket systems M-13, M-8. and others. Twice laureate of State Prizes of the USSR (1946, 1947), Doctor of Technical Sciences 1944), Professor (1950), Honored Worker of Science and Technology of the RSFSR (1970). From 1947 to the end of his life he headed the department of the Moscow Institute of Chemical Technology. Mendeleev.

In 1928, A.S. Bakaev was the first to propose a specific recipe for domestic nitroglycerin powder, which could be used, along with standard pyroxylin powder, for the manufacture of artillery propelling charges.

This gunpowder, called NG, had the following mass composition: colloxylin - 56.5%; nitroglycerin - 26.5%; dinitrotoluene - 9%; dinitroanisole - 5%; centralite - 2%.

Since 1928, work on nitroglycerin gunpowders has become widespread, especially after the creation of a brigade under the leadership of A.S. Bakaev, which included young talented employees B.P.Fomin, I.G. Lopuk, and others. At the Morozov plant, with the active participation of its technical director A.D. Artyushchenko, a pilot plant for the prescription-technological processing of gunpowder was created. The head of the pilot plant was A.V. Sukhanov.

First of all, tubular powder was manufactured for the 76-mm regimental gun of the 1902 model.Since the manufacture of gunpowder encountered great technological difficulties (high pressing pressure, a large number of flashes on the rollers due to insufficient plasticity of the powder mass), additional studies were carried out on clarification of the powder composition to improve its technological properties. The problem was solved by introducing 1% petroleum jelly into the powder as a technological additive. The letter B was added to the name of gunpowder and gunpowder became known as NGV.

The final composition of ballistic nitroglycerin powder, after some additional refinements of the recipe received the index H, is given below / 2 /:

colloxylin - 57%;
nitroglycerin - 28%;
dinitrotoluene - 11%;
centralite - 3%;
petroleum jelly - 1%.

It was this gunpowder that was the basis of all subsequent modifications of nitroglycerin ballistic powders. A technological process for obtaining these propellants was also developed, which consisted of the following main operations: preparation of propellant components, preparation ("cooking") of the propellant mass, squeezing out excess moisture, rolling the propellant mass, rolling, forming propellant tubes on hydraulic presses, cutting them to the required length, sorting of checkers, mixing and packing.

The positive results of work on the creation of domestic formulations of nitroglycerin ballistic powders and the technology for their manufacture have created the prerequisites for the design and construction of an experimental workshop capable of providing propellants for extensive ballistic testing and processing.

The confidence of the team of scientists, led by A.S. Bakaev, in the development of ballistic propellants, in the correctness of their scientific, technical and technological solutions, the urgent need for the practical implementation of the results of the work performed, the awareness of their importance for the country were an incentive for making a bold engineering decision related to a certain risk, but promising, if successful, a huge gain in time - the decision to design and build not only an experimental workshop for the production of ballistic powder at the plant. Morozov, but also a large powder production at one of the factories in the south of Ukraine. In the design of both objects, L.S. Bakaev, as the author of the powder formulations and technology, was directly involved.

Experimental workshop at the plant. Morozov was commissioned already in 1931. The construction of the South Ukrainian gunpowder plant was completed in 1934, and in the same year the development and production of artillery nitroglycerin ballistic powders began there / 3 /.

Information about the work of the South Ukrainian plant for the development of the production of ballistic powder is given in the detailed memoirs of Ivan Vasilyevich Kryzhanovsky, who worked at this plant during the described period and was directly involved in the creation of production technology and the development of the production of gunpowders and charges / 3 /. Without these memoirs, written in 1977, it would have been impossible to objectively illuminate the most important stage in the creation of missile charges from ballistic powder.

The first gunpowder nomenclature mastered by the plant during the launch period was ballistic tubular powder K with an outer tube diameter of 3.2 mm, a rope diameter of 1.2 mm and a length of 245 mm. The gunpowder was intended for the 76 anti-aircraft dukes of the 1931 model.

It should be especially noted the significant difficulties that arose in the manufacture of ballistic powder at the stage of its development.

First of all, we faced the fact of a sharp influence of the supplied colloxylin on the manufacturability of the composition and the quality of the powder. The fact is that the South Ukrainian gunpowder plant did not have colloxylin production and received colloxylin from other gunpowder plants.

The most easily processed powder mass made on the colloxylin plant. Morozov, and, conversely, colloxylin supplied by one of the factories in central Russia had completely unsatisfactory technological qualities. In the manufacture of gunpowder on colloxylin of this plant, not only did the accident rate increase during the pressing phase, but many products were rejected due to the unsatisfactory appearance of the gunpowder (superficial "herringbone", noncentricity, "brindle" along the channel, etc.).

During the development of the composition, there was a very high accident rate when rolling the powder mass on horizontal rollers. There were other difficulties, the matter was complicated by the fact that control over the observance of technology was practically impossible, since at first there was no fixed procedure for the technological process.

At the beginning of 1935, under the leadership of A.S. Bakaev, an authoritative commission was created, which included employees of the Moscow Powder Institute B.P. Fomin, V.S. Dernova, as well as employees of the powder factory V.S.Bondar, I.V. Kryzhanovsky and others. The Commission analyzed the entire technological process, identified the causes of difficulties and developed measures to eliminate them. In particular, it was found that the reason for the high accident rate during rolling on horizontal rollers was the etching of the surface of the rolls as a result of their treatment with hydrochloric acid, in order to increase the gripping ability of the rolls. In this case, deep shells were formed - centers of flares. Etching was strictly prohibited and was replaced by rubbing the rolls with an emery stone.

At all stages of production, technological regulations were introduced and their strict observance was ensured, production discipline was increased, personnel training was organized.

As a result of the work carried out, the production of nitroglycerin ballistite powder at the plant has stabilized, the accident rate at all phases has sharply decreased, technological defects have decreased, and labor productivity has increased.

Already in 1935, the plant supplied large enough quantities of tubular gunpowder intended for the assembly of propelling charges for naval artillery systems. The outer diameter of the manufactured powder tubes reached 20 mm, and their length - up to 650 mm, and both the diameter of the tubes and their length, if necessary, could

be increased. Thus, the problem of manufacturing propelling artillery charges from nitroglycerin ballistic powder was solved.

This meant that the objective prerequisites for the manufacture of missile charges from ballistic powder at the South Ukrainian plant were created.

However, for the time being, no practical conclusions were drawn from this. Two scientific and technical directions: the creation of rockets, on the one hand, and the development of nitroglycerin ballistic powders, on the other, have been developing in isolation from each other for almost 10 years.

Replacement of pyroxylinotrotyl powder with nitroglycerin ballistic powder in aircraft rockets RS-82 and PC-132

As mentioned above, testing of aircraft missiles RS-82 and PC-132 in 1933, due to the impossibility of supplying the required quantities of rocket charges made of pyroxylinotrotyl powder, practically ceased. And, as has already happened more than once in the history of science and technology, the solution to the problem turned out to lie at the junction of various scientific and technical areas, the development of which, up to a certain point, proceeded independently of each other.

How the first meeting of the employees of the RNII, who developed the designs of rockets, and the employees of the Moscow Powder Research Institute, who created the formulations of nitroglycerin ballistic propellants, took place, is described in the memoirs of the direct participant in the development of formulations of propellants and rocket charges from these propellants - Vladimir Sergeevich Dernovy / 4 /.

These memoirs were written by him at the request of the author in October 1984 and cover in detail the progress of work at the first, most crucial stage of the creation of missile charges from ballistic powder for the RS-82 and PC-132 aircraft shells.

"In the middle of 1933 - VS Dernova recalls - the laboratory of nitroglycerine gunpowder at the Research Institute, headed by A.S. Bakaev and B.P. Fomin, was visited by representatives of the Russian Research Institute - a group of three or four people, including V. A.Artemyev and F.N. Poida - with the aim of clarifying and searching for the possibility of replacing pyroxylinotrotyl powder in the RS-82 and PC-132 rockets.

According to the arrivals, the technology of manufacturing PTP (blind pressing) made it possible to obtain only checkers of limited length and, most importantly, excluded the possibility of their mass production in industrial conditions due to their low productivity and increased danger. To further advance the current work and successfully solve the general problem, it was urgently required to replace the PTP gunpowder in the PC, and the arrivals turned to the specialists of the research institute with a request to recommend to them for use in the PC any specific gunpowder that would be most suitable for this purpose, was suitable for mass manufacture in industrial conditions and could already be manufactured now or in the very near future in sufficiently large quantities.

In response to this, representatives of the RNII were immediately recommended to use gunpowder N for PC, developed by that time for artillery systems (there were no other ballistic powders, including special compositions, then).

At the same time, it was emphasized that the specialists of the research institute did not doubt the possibility of manufacturing and using gunpowder H for PC, the technology of this gunpowder makes it easy to manufacture powder tubes of almost any required length and that lengthening the powder tubes to the size of the rocket chamber will not only simplify the design for making the charge, but should noticeably improve its ballistic qualities ... "/ 4, p. 1 /.

Further from the same memories:

"Since ballistic nitroglycerine gunpowder at that time could only be produced in the experimental workshops of the Morozov plant, then, given the importance and urgency of the case, representatives of the RNII and the Moscow Powder Institute immediately went to this plant, where soon pilot production of tubular nitroglycerin powder with a diameter of 24 and 40 mm.

At the beginning of production we encountered certain difficulties. In some cases, during bench tests of manufactured charges, the gas pressure in the rocket chamber increased sharply. It was found that the reason for these unintended pressure increases was an increase in the combustion surface area due to the presence of encapsulated air in the propellant, so-called air inclusions. It took a long time to fight them. But in the end, the technology was brought to the required level, and charges of ballistic powder H in the rocket chambers of the

RS-82 and PC-132 aircraft shells began to burn naturally. As a result, the plant them. Morozov made charges in quantities sufficient for "conducting extensive bench and firing tests" / 4, p. 2 /.

The tests of the RS-82 and PC-132 shells, which had stopped, were resumed at one of the test ranges in 1935. A detailed account of these tests is contained in the book "First Launches" / 5 /. The particular value of the facts given in this book lies in the fact that one of its authors, at that time a 28-year-old engineer, Yu.A. Pobedonostsev, was not only a direct participant in the development of rockets, but also headed a team to test them.

"During the experiments," Pobedonostsev recalled, "suddenly had to face an incomprehensible phenomenon. On one of the cold autumn days, the already tested shells suddenly refused to fly as they were supposed to: after launch, they flew 3-5 m ahead, fell on After a thorough analysis, it was found out that the critical section of the nozzle, selected at normal temperature for PTP checkers, was unsuitable at low temperatures for gunpowder bumps N. It turned out to be serious: several hundred shells for field tests with such nozzles were made. The checkers were no longer made from PTP. In order not to disrupt the tests, it was decided to immediately select and comprehensively check the new size of the critical section of the nozzle for the N powder checkers.capable of ensuring their normal combustion at any practically possible temperature.

To use the shells already made, it was decided to insert additional bushings from the nozzle into the throat, reducing the flow area for gases. Hundreds of shells were reloaded in tents at the range. People worked day and night, in rain and snow. The tests did not stop for a single day. The test results, both in the accuracy of fire and the effectiveness of the shells at the target, exceeded all expectations "/ 5, p. 30 /.

The issue of mass production of rocket charges for aircraft projectiles RS-82 and PC-132 has become a priority, which is why scientists and engineers of the powder industry in 1927-1934. the work was extremely important for the country, since in. As a result, not only formulations of ballistic propellants were created, but also a plant was built, which was able to ensure the supply of rocket charges in the required quantities.

Since 1935, the production of rocket charges for aircraft shells RS-82 and PC-132 due to the growing demand for them was transferred to the South Ukrainian plant. The development of the production of gunpowder N and the manufacture of charges from it was carried out in the same way as at the plant. Morozov, under the author's control of A.S. Bakaev, B.P. Fomin, V.S.Dernovy.

The experience gained by the plant in the manufacture of ballistic powder for naval artillery made it possible to immediately begin the manufacture of charges of 24 / 6-57 mm intended for the RS-82 rocket.

The size and appearance of the first samples of gunpowder sticks fully met the requirements of the RNII. It was necessary to check the nature of the combustion of gunpowder in a rocket chamber. The indicators characterizing the work of the charge at that time were the value of the maximum pressure in the chamber, determined by the compression of the crasher columns, and the pressure spread in the rocket chamber.

Experiments on the combustion of powder bills, carried out in the material part delivered to the plant by Yu.A. Pobedonostsev, showed quite acceptable results (due to the lack of test stands, the tests were carried out on the open site of the plant's landfill) and served as the basis for the next stage - working out the technology of obtaining checkers with a diameter of 40 mm for the PC-132 aviation projectile. The drawings of the press tool were developed by I.V. Kryzhanovsky.

As mentioned above, the length of the powder sticks (57.5 mm) was set at that time forcibly, based on the technological capabilities of their manufacture by deaf pressing from PTP. Although the technology for making ballistic propellants did not limit the length of the checkers, it was nevertheless necessary, before the comparative tests of charges from the PTP and N propellants, to make the propellant N propellant charges as short, i.e. 57.5 mm. Later, after comparative tests of charges consisting of short and long checkers, they switched to making charges from checkers, the length of which was approximately equal to the length of the rocket chambers, namely 230 mm for the RS-82 and 287.5 mm for the PC-132 (see Fig. 1, b and 2, b). The subject of special concern of specialists in the manufacture of rocket charges was the fight against air inclusions in powder bills.

The issue was resolved in a compromise way: both by further improving and regulating the technological process while increasing the discipline of production, and by regulating the permissible defects in the powder bills, which were determined in the course of bench tests of charges with air inclusions, different in quantity and size.

Yu.A. Pobedonostsev recalls: “We had to introduce tough rejection, thorough mixing of checkers made on different presses, and a whole series of other new operations. New production conditions, and somewhat different equipment, and finally, different climatic conditions also affected. it was noticed that if a batch of

powder bombs was handed over to the technical control department in the early morning, then the pressure in the chambers during combustion was normal. In the afternoon, the pressure, as a rule, increased, and the whole batch of bombs was rejected. On cold nights, the charges cooled down, and the party gave normal pressure. During the day, the control charges were very hot and gave an increased pressure that did not fit into the permissible limits "/ 5, p. 33 /.

Numerous bench tests of rocket engines with charges made of nitroglycerine ballistite propellants carried out at the South Ukrainian plant under a wide variety of conditions of rocket engine equipment and at different charge temperatures provided a rich source material for the development of methods for calculating the charge, selecting the diameter of the critical section of nozzles, etc., as well as for serious theoretical generalizations.

In the annual collections of articles "Rocket technology", published at the RNII, articles began to appear systematically on the design and calculation of rocket charges and engines.

The first such publication was the article by Yu.A. Pobedonostsev "On combustion of a long charge in a rocket chamber with free stacking of checkers" (1937) / 6 /. In 1938 the second article by Yu.A. Pobedonostsev "Selection of a nozzle to a rocket charge" was published in the same collection / 7 /. In 1937, the collection "Rocket technology" published an article by VG Bessonov "Analytical determination of the size of the nozzle throat and the conditions for normal combustion of the rocket engine powder charge" / 8 /.

Especially important for all subsequent practice of designing and calculating charges was the introduction by Yu.A. Pobedonostsev of a parameter or criterion for loading a rocket engine, which later received the name of its author. As is known, the Pobedonostsev parameter is equal to the ratio of the area of the total burning surface of the rocket charge (except for the surface of one end) to the free passage area for gases in the plane of contact of the charge with the reference diaphragm.

The calculations carried out by Yu.A. Pobedonostsev showed that for charges made of tubular sticks of nitroglycerin ballistic powder H, the geometric value of the loading parameter and the highest velocity of the gas flow in the chamber (in the plane of the diaphragm) are approximately equal.

At the beginning of 1937, the field tests of RS-82 aircraft projectiles with charges of ballistic powder N, manufactured by the powder factory, were repeated on a large scale using aircraft of various types and, according to Yu.A. Pobedonostsev, showed good results / 5, p. ... 37 /. After successful tests on seven fighter aircraft in December 1937, 82-mm rockets were adopted by the USSR Air Force. In July 1938, after successful military trials, PC-132 rockets were adopted by bomber and assault aircraft.

Rocket charges from nitroglycerine ballistic powder for ground forces rockets

The most massive rocket projectile used by the ground forces of the Soviet Army during the Great Patriotic War was the 132-mm M-13 projectile. Of great interest is the history of the development of a rocket charge for this projectile, closely related to the history of the creation of a rocket projectile as a whole.

The tactical and technical assignment for its development was issued by the Main Artillery Directorate by the RNII in June 1938/5, p. 40 /. For the fastest execution of the task, the experience of creating the PC-132 aviation projectile was used to the maximum. By December 1938, an experimental batch of 132 mm rockets had already been manufactured, the design and ballistic characteristics of which differed little from the characteristics of the previously developed PC-132 aviation projectile. From December 1938 to February 1939, field tests of the manufactured shells took place / 5, p. 42 /.

The commission that conducted the tests, pointing out a number of shortcomings of these projectiles (refusals and delays in ignition, insufficient firing range, low accuracy, as well as a number of serious shortcomings of launchers), in its conclusion, nevertheless, noted that the missiles presented for military tests shells, while eliminating these shortcomings, are a reliable means of artillery weapons and a valuable contribution to the development of rocket and artillery / 5, p. 42 /.

In connection with the comments of the commission, the teams of the RNII and the Moscow Powder Research Institute carried out the revision of both the projectile as a whole and its rocket charge, primarily in order to eliminate the largest drawback of the projectile - short range. It turned out to be possible to eliminate this drawback in the simplest way: to increase the length of the powder bills, and, consequently, the mass of the charge by about two times, without changing other geometric dimensions of the powder bills. The range of the M-13 projectile increased to 8.5 km (instead of 6 km for the PC-132) with a simultaneous increase in the mass of the warhead /5, p. 46/.

“Significant work was carried out to increase the accuracy of the projectile. For this, firstly, we improved the design of the support diaphragm, which reduced and stabilized the release of unburned powder particles, and, secondly, increased the rigidity of the projectile stabilizers by replacing cast duralumin stabilizers with stamped steel ones with longitudinal corrugations.

Finally, delays and failures in the ignition of charges were eliminated by replacing the igniter in a plain cap with a moisture-resistant igniter in a hard case, as well as by introducing a duplicate ignition system.

The general view of the rocket charge for the M-13, determined as a result of the work described above, is shown in Fig. 3.

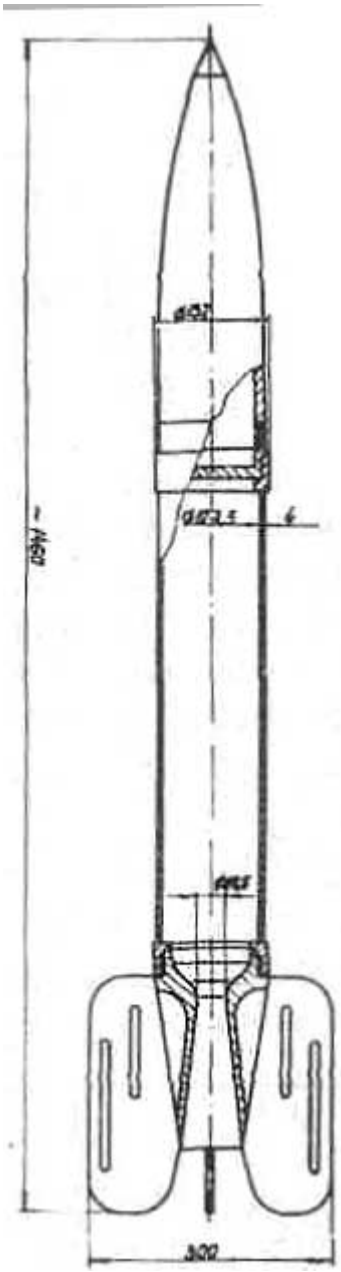

Fig. 3. Rocket charge to rocket charge M-13

Fig. 4. Reactive charge M-13

The charge consisted of seven cylindrical single-channel sticks with an outer diameter of 40 mm and a channel diameter of 3 mm. The charge length was 550 mm. The charge was made initially from gunpowder N, and then from gunpowder NDK, NM-2, NM-4Sh. The mass of the charge was set equal to (7050 ± 35) g, and for gunpowders NM-2 and NM-4Sh. (7130 ± 35) g.

Ignition of the charge was provided by one gunpowder igniter of the DRP type weighing 50 g, located in the bottom of the rocket chamber. Ignition of the igniter was carried out with the help of two glow plugs, into which PP-5 squibs were inserted. A charge with an igniter was placed in a rocket chamber, the diagram of which is shown in Fig. 4. The characteristics of the M-13 rocket engines are given in Table I.

Table I.

Basic characteristics of rocket engines of rockets (steel body, no thermal insulation)

Options	M-13	M-8	M-31
Rocket engine body weight, kg	14	4.1	29
Inner diameter of the case, mm	123.5	73	128
Case wall thickness, mm	four	3.5	five
Nozzle throat diameter α_{cr}, mm	37.5	19	45
Nozzle socket diameter α_{a}, mm	75	43	76.5
Ratio α_{a} / α_{cr}	2	2.26	1.7
Pobedonostsev criterion	170	one hundred	160
Charging density, g / cm ^{3}	1.15	1.0	1.0
Engine mass perfection factor α	1.95	3.5	2.6
Engine intensity index β, kgf / kg	95	55	70

Notes:

1. Coefficient of mass perfection of the engine - the ratio of the passive mass of the rocket engine to the mass of the rocket charge;

2. The engine intensity indicator is the ratio of the total practical impulse of the engine reactive force to its passive mass.

The characteristics of the rocket engine for the M-13 can be used as a starting point for comparative assessments of new developments.

From September 29 to November 9, 1939, the M-13 rocket with the missile charge described above was subjected to extensive field tests. In all cases, the rocket charge worked stably. The tests passed with a positive result. However, the essentially unjustified one and a half year delay in subsequent tests led to the fact that the mass production of M-13 rockets before the war was not deployed.

Marshal of the Soviet Union G.K. Zhukov in his book "Memories and Reflections" noting: "Marshal G.I.Kulik, being the main speaker of I.V. By the beginning of the war, the Main Artillery Directorate did not fully appreciate such a powerful rocket weapon as BM-13 (Katyusha) "/ 9, p.198 /.

Indeed, the industry received orders only for the manufacture of pilot batches. So, in 1940 the factories produced only 1000, and before May 1, 1941 - 10788 M-13/5, p.48 / shells. "

From June 15 to June 17, 1941, a review of samples of new weapons took place at the test site near Moscow. In particular, salvo firing with M-13 projectiles was carried out. The People's Commissars of Defense S.K. Timoshenko who were present at the review, weapons of D.F. Ustinov, ammunition P.N. Goremykin and Chief of the General Staff G.K. Zhukov praised the new rocket weapon.

On June 21, literally a few hours before the start of the war, it was decided to launch mass production of M-13 rockets and BM-13 launchers and to start forming missile military units / 5, p.49 /.

Before World War II, an 82 mm M-8 missile was also created for the ground forces. This projectile, developed on the basis of the RS-82 aviation projectile, was put into service in August 1941. The rocket charge for the M-8 rocket projectile was initially manufactured from gunpowder N, consisted of seven cylindrical checkers with an outer diameter of 24 mm and a channel diameter of 6 mm ... The charge length was 230 mm (Fig. 5, a). The mass of the charge was 1040 ± 10 g.

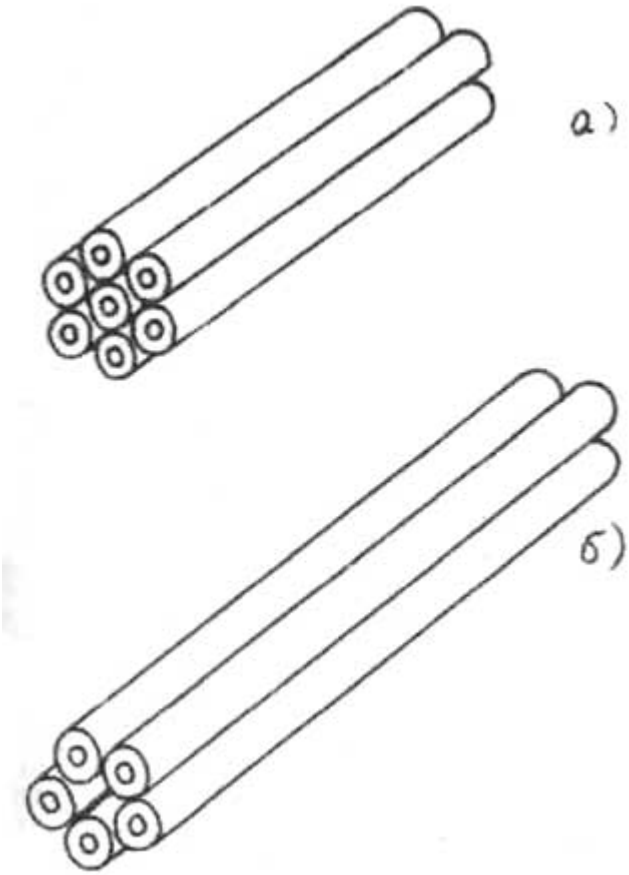

Fig. 5. Rocket charge for the M-8 rocket.
a - until 1943;
b - 1943-1945

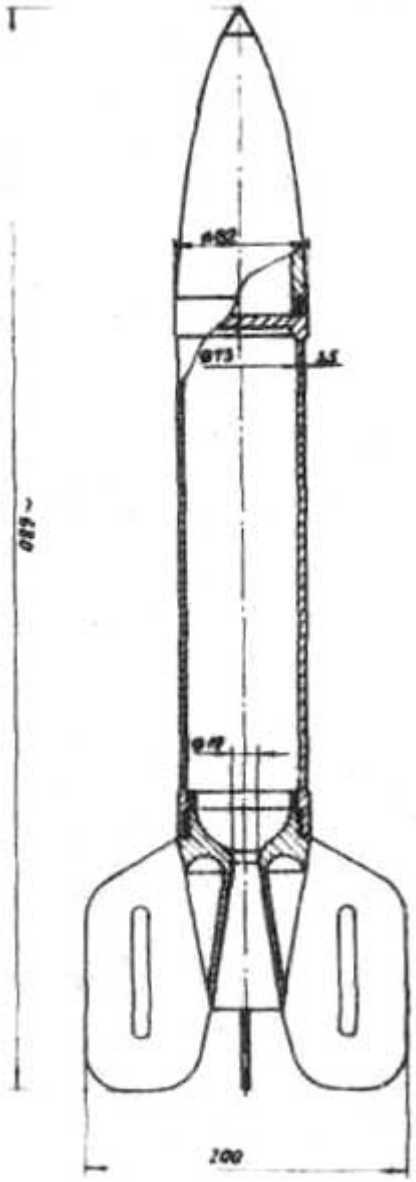

Fig. 6. Rocket M-8

In order to increase the flight range of the M-8 projectile, the Special Bureau of the Sredneuralsk plant carried out experimental design work in 1942, using rocket chambers with a length increased to 290 mm. Employees of the Special Bureau designed a number of charge options, including telescopic, single-shaft seven-channel, etc. After bench and firing tests of all versions, a charge of NM-2 gunpowder was adopted for the M-8, which consisted of five checkers with an outer diameter of 26.6 mm , channel diameter 6 mm, length 287 mm (Fig. 5, b) and charge mass (1180 ± 10) g. This charge provided an increase in the flight range of the M-8 projectile to 5.5 km / 10; 11 /.

Ignition of the charge was carried out by two igniters of their gunpowder type DTP with a mass of 11 g, placed in the bottom and tail parts of the rocket chamber. Ignition of the ignitors was provided by PP-5 pyrotechnical cartridges. The charge with ignitors was placed in the rocket chamber (Fig. 6). The characteristics of rocket engines for M-8 are given in Table I.

In the course of the Great Patriotic War, more and more new combat missions arose in front of the rocket artillery: increasing the firing range and power of the missile warhead, increasing the accuracy. The main prerequisite that determined the success of solving these very complex problems in the shortest possible time was the correct choice of the general direction of development, namely, their implementation on the basis of unification of the most responsible for labor-consuming element of the projectile - the rocket charge.

The rocket charge developed for the M-13 projectile was used as the main one, which, without any changes in the powder composition, as well as the mass and geometric characteristics of the charge, was used to create four more rockets (Fig. 7). So, in June 1942, shells with a mass of warheads about 1.5 and 2.5 times greater than

that of the M-13 projectile were put into service with the army. They received the names M-20 and M-30, respectively. Naturally, the firing range of these shells decreased and amounted to 5 km for the M-20 and 2.8 km for the M-30/5, p.59 /.

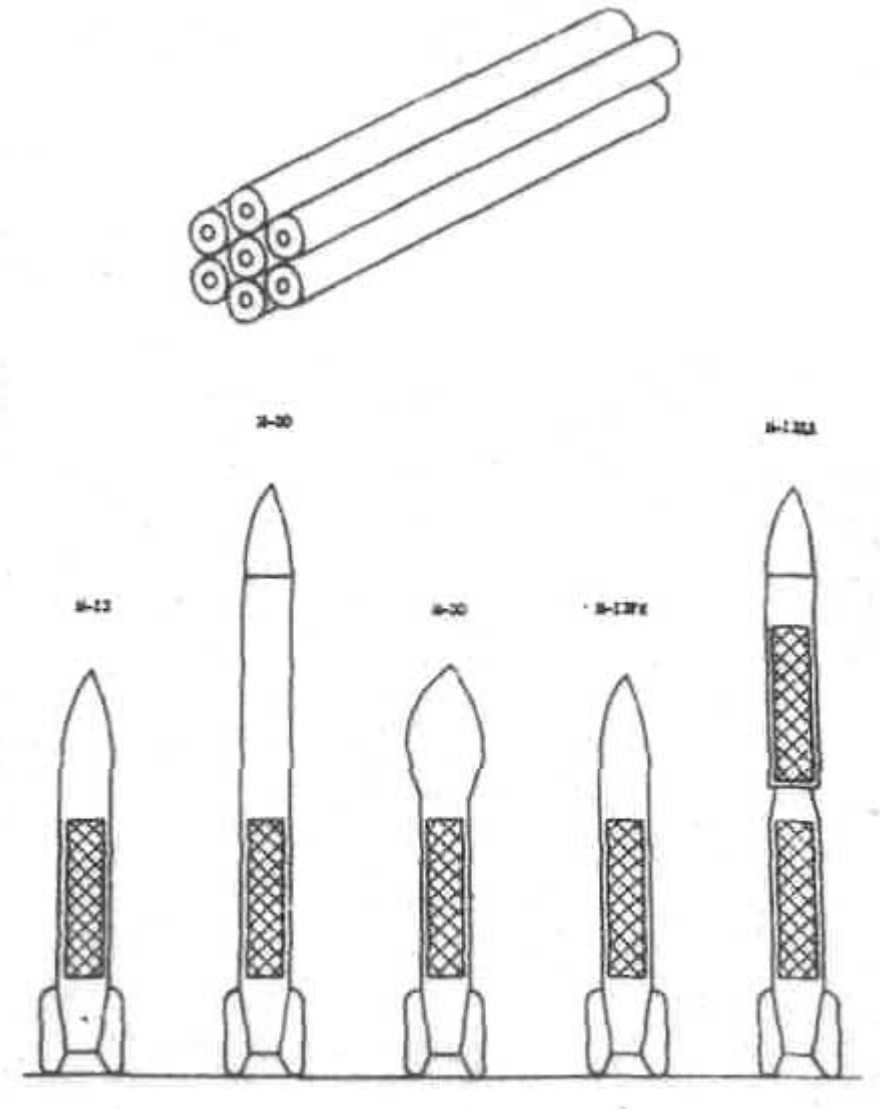

Fig. 7. Rocket projectiles developed on the basis of the M-13 rocket charge.

In April 1944, the army received a round with an accuracy almost twice as good as that of the M-15 round. The improvement was achieved without stricter requirements for the rocket charge and without any change in it, only by introducing 12 oblique peripheral holes into the engine design, which ensured the projectile's rotation on the trajectory and thereby sharply reduced the negative effect on the accuracy of the projectile eccentricity. This projectile became known as the M-13UK (improved accuracy). In October 1944, on the basis of the M-13 rocket charge, a projectile was put into service, with a firing range of about 11.8 km, i.e. almost 1.5 times more than the M-13 projectile. The increase in range was achieved through the use of two M-13 engines operating simultaneously. The projectile was named M-13DD (long-range).

As mentioned above, the M-30 projectile with a powerful warhead had a firing range of only 2.8 km, i.e. three times less than the firing range of the M-13 projectile. This was a serious flaw. To increase the firing range, at least one and a half times, it was necessary to create a new rocket charge.

Such a charge was developed by the employees of the Special Bureau of the Middle Urals plant A.S. Bakaev, S.N. Razumovsky, S.A. Ilyushenko, D.I. Galperin / 12 /. It consisted of five powder bills with an outer diameter of 46 mm, a channel diameter of 8 mm, and a length of bricks of 900 mm (Fig. 8). The charge was made from

HM-31 and H-31 propellants specially designed for the new projectile / 13 /. The mass of the charge was about 11.2 kg, i.e. almost 1.5 times the mass of the charge for the M-13.

Fig. 8. Rocket charge for rockets M-31 and M-31 UK.
a - until 1943;
b - 1943-1945

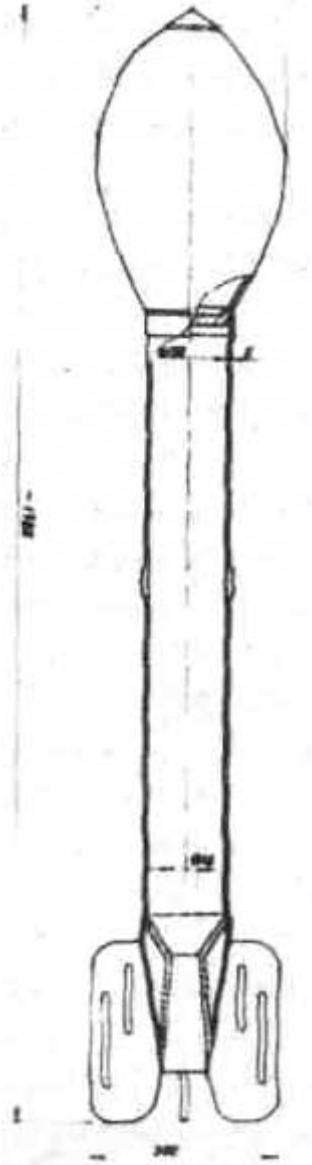

Fig. 9. Rocket projectile M-31

Ignition of the charge was provided by an igniter with a mass of 75 g made of RTP powder, located in the bottom of the rocket engine. Ignition of the igniter was carried out using a platinum-iridium electric igniter. The charge with the igniter was placed in the rocket chamber (Fig. 9). Rocket engine characteristics For M-31 are given in Table I.

On the basis of the charge described above, a new M-31 rocket with a range of up to 4.3 km was developed and entered service with the army in March 1943. In order to increase the accuracy of this projectile, a little later, its rocket engine was equipped with four fittings with L-shaped holes, which ensure the rotation of the projectile. This projectile entered service with the army in April 1944. It was named M-31UK.

The development of substantiated requirements for missile charges by the Special Bureau of the Central Ural Powder Plant was of invaluable importance for improving the quality and, consequently, the quantity of rocket charges for rockets produced by gunpowder factories. These requirements took into account both the practical experience of making charges by gunpowder factories and the experience of the combat use of rockets on the fronts of the Great Patriotic War.

The requirements were formulated in the form of technical specifications for the manufacture and reception of rocket charges for the M-13, M-8 and M-31. All three documents were approved by the leadership of the

NKB of the USSR and the command of the Main Directorate of Armament of the Guards Mortar Units of the Supreme High Command Headquarters (GUVGMCH SVGK) on July 6, 1943/14; 15; 16 /.

These technical specifications not only played "an exceptional role in the production of missile charges in 1943-1945, but also served as the basis for the development of technical documentation for missile charges in the post-war period. Considering that this technical documentation accumulates invaluable experience in the production of missile charges during the war. , I will give a brief summary of the main content of the described technical conditions, taking as a basis the specifications for the manufacture and reception of charges for the M-13 projectile.The requirements and structure of the specifications for charges to the M-8 and M-31 are similar to those for the charge to the M-13.

TU consisted of ten sections (definition and purpose, indexing, technical requirements, TU for starting materials, charging charges, sealing, marking, acceptance rules, test methods and storage rules), and three annexes (a list of TU and OST required for manufacturing and acceptance, instructions for the production of bench tests and chemical analysis of propellants). A drawing for a powder charge was not developed. All the data necessary for the manufacture of charges were contained in the TU.

I will dwell in more detail on some of the wording and requirements of the TU. For the first time, the indexing of the rocket charge was introduced into the technical documentation, which contained in a very short form the necessary minimum of information about the manufactured charge.

The batch index of charges was represented by a fraction, the numerator of which indicated the name of the propellant, the symbolic designation of the rocket for which the batch of charges was made (the batch number of the gunpowder, the year of its production and the symbolic designation of the manufacturing plant. and the symbol of the manufacturer.

In the "Technical Requirements" section, the chemical composition of the propellants used for the manufacture of charges was given, and the tolerances for the content of the components were indicated, as well as the requirements for the caloric content of the propellant. x)

x) In the post-war years, the term “calorific value” is used instead of the term “calorific value”. In this work, the author retains the terminology of 1941-1945.

It was emphasized that the caloric content of gunpowder should be determined both during phase-by-phase control of powder mixtures and in finished products. Requirements for the dimensions of the powder cartridges (outer diameter, channel diameter and length), with tolerances, were given directly in the TU. It was indicated that one checker with a diameter of 0.2 mm below the lower limit and one shortened checker can be introduced into the charge, provided that the requirements for the mass of the charge are met. The tolerance of the checker was allowed (but not more than 1.5 mm), as well as the non-parallelism of the ends, the ovality and obliqueness of the cut (within the size tolerances). The straightness of the individual checkers was not checked, but the full charge had to enter the control chambers freely, without effort.

The TU formulated requirements for the appearance of powder bills. Checkers that had four types of external defects were not allowed: end air inclusions, cracks on the surface, a distinct layered structure at the ends, clearly pronounced traces of needle holders on the ends and lateral surface. Checkers were allowed with spalls along the end from the outer surface, if the length and thickness of the spall was less than 5 mm, with foreign inclusions (wood, paper) with an area of up to 5 mm ^{2} , and no more than three, with a rough surface (a standard was set), with surface air inclusions along the entire length, blocks up to 2 mm wide and up to 1 mm deep.

It was established that the moisture content of the powder should not exceed 1%, and the specific gravity of the powder should be at least 1.57 g / cm. Requirements were made for the chemical resistance of gunpowder:

Abel's test at 82 ° C - not less than 8 min;

Abel's test (repeated) at 106.5 ° C - not less than 25 hours,

test until brown vapor appears at 132 ° C - not less than 100 min.

The manufactured charges were subjected to bench tests in series of seven counting burnings only at a positive charge temperature of 40 ° C (tests at a negative charge temperature, as a rule, were not carried out). During the tests, only the gas pressure was determined.

The pressure in each of the experiments was not allowed to exceed 285 kg / cm ^{2} , and the average pressure in the series should not exceed 250 kg / cm 2. For formulations N and NDK, it was additionally required that the average pressure in the batch was at least 175 kg / cm2, otherwise the tests were carried out at a temperature of minus 40 ° C. The party was accepted if there were no fades and pops. If during the tests the requirements for

the average or maximum gas pressure were not met, then the batch of charges was returned to the plant for correction and, upon re-presentation, was tested in a series of 14 experiments.

Requirements were also made for the stability of the ballistic characteristics in the party. The deviation of the maximum and minimum pressures from the average could not exceed ± 13%. Requirements for the full impulse of the reactive force, as well as for the operating time of the charge, were not imposed. In the "Equipment" section, the number of checkers in the charge, the mass of the charge with a tolerance, etc. was indicated.

In the section "Reception rules" it was stated that charges are presented to a military representative in batches of 500 to 5000 sets (it is possible in parts, but not less than 10 boxes). For external inspection and measurement, at least 5% of the charges were taken, and 20-30 pieces were selected for measurement and production of physical and chemical tests. The TU emphasized that the charges should be manufactured according to the technological regulations approved by the USSR NKB.

Table 2 shows the characteristics of charges for the RS-82 and PC-132 aircraft projectiles, as well as for the M-13, M-8 and M-31 projectiles, indicating the manufacturing tolerances that guided the manufacture of charges during the Great Patriotic War.

table 2

Characteristics of rocket charges for rockets of the Soviet Army during the Great Patriotic War

Options	Rocket projectiles				
	Aviation		Land		
	RS-82	PC-132	M-13	M-8	M-31
Gunpowder brand	H	H	N, NDK, NM-2, NM-4Sh	NM-2	H-31, HM-31
Rocket charge mass, g	1040 ± 10	3500 ± 35	7050 ± 35 (N, NDK) 7130 ± 35 (NM-2, NM-4Sh)	1180 ± 10	11250 ± 50 (H-31) 11150 ± 50 (HM-31)
The number of powder bills in the charge, pcs.	7	7	7	five	five
Checker sizes with tolerances:					
outer diameter, mm	24 ± 0.6	40 ± 1	40 ± 1	26.6 ± 0.6	46 ± 1
channel diameter, mm	6 ± 0.5	8 ± 0.5	8 ± 0.5	6 ± 0.5	3 ± 0.5
checker length, mm	230 ± 3	287.5 ± 3	550 ± 5	287 ± 3	900 ± 10

Table 3 shows the compositions of ballistic propellants taken from TU, used during the Great Patriotic War for the manufacture of rocket charges for M-13, M-8, M-31 projectiles, indicating the tolerances for the content of the components.

Table 3

Compositions of ballistic propellants for missile charges PC of the Soviet Army during the Great Patriotic War

Powder components,%	Gunpowder						
	H	NDK	NM-2	NM-4SH	H-31	HM-31	Tolerance,%
Colloxylin	57	56	54	54	56	55	± 1.0
Nitroglycerine	28	thirty	27	25	29	27	± 0.7

Dinitrotoluene	eleven	-	15	17	11.5	15	± 1.0
Magnesium oxide	-	-	2	2	0.5	2	± 0.5
Vaseline or transformer oil	one	one	2	2	one	one	± 0.5
Centralite	3	3	-	-	2	one	± 0.5
Dinitroxylene		ten	-	-	-	-	± 1.0
Caloric content of gunpowder, kcal / kg	870	870	880	845	915	915	± 1.0

Table 4 shows, for reference, some of the characteristics of the main rockets during the Great Patriotic War.

Table 4

The main characteristics of rockets of the ground forces of the Soviet Army during the Great Patriotic War

	Rocket projectiles							
	M-8	M-13	M-20	M-30	M-13UK	M-13DD	M-31	M-31UK
Caliber, mm	82	132	132	300	132	132	300	300
Projectile length, mm	714	1415	2090	1450	1415	2120	1760	1760
Projectile weight, kg	8	42.5	58	72	42.5	62.5	92.5	94.5
Warhead weight, kg	2.7	21.3	37.1	52.4	21.3	21.3	52.4	52.4
Firing range, km	5.5	8.47	five	2.8	7.9	11.8	4,3	4.0
Accuracy by range	1/50	1/65	1/80	1/35	1/105	1/100	1/45	1/80
Accuracy in the direction	1/45	1/40	1/40	1/20	1/85	1/85	1/20	1/50
Date of adoption	VIII.41	VI.41	VI.42	VI.42	IV.44	X.44	III.43	IV.44

Scientific and technical support for the production of rocket charges from nitroglycerin ballistic powders in 1941-1945.

Immediately after the beginning of the Great Patriotic War, the manufacture of rocket charges for rockets of the ground forces M-13 and M-8 was entrusted to the South Ukrainian gunpowder plant. The experience gained by this plant in the manufacture of rocket charges for aircraft missiles RS-82 and PC-132, of course, was used in the manufacture of rocket charges for M-8 and M-13, and therefore the experimental and technological development of the production of these charges by the plant was quickly and successfully completed.

However, the development and approval of technical documentation for the manufacture of gunpowder, charges from it and the rules for acceptance by the controlling services lagged noticeably behind. By order of the USSR NKB, the development of technical documentation was entrusted to a commission chaired by the head of the technical department of the South Ukrainian plant I.V. Kryzhanovsky. The commission included researchers from the Moscow Powder Institute - V.S.Dernova and the RNII - V.G. Bessonov, a representative of the Morozov plant and representatives of the military acceptance of the Air Force.

During the development of technical documentation, one of the significant disagreements was the value of the tolerance for the outer diameter of the powder cartridge for the charge to the M-13 projectile. The peculiarities of the technological process, the relaxation properties of the powder to be pressed, the statistical data on the measurement of checkers from the pilot batches indicated that an acceptable tolerance for the outer diameter of the powder checker equal to 40 mm could be 1 mm for mass production of products. This amount of admission was considered reasonable by the majority of the commission members and was submitted for approval.

However, contrary to the production capabilities, TUs were approved with an outer diameter tolerance of 0.5 mm. This circumstance immediately reduced, due to a large defect in the outer diameter of the checkers, the release of charges for the M-13. The effectiveness of the first salvoes of the guards' Katyusha mortars required

the adoption of urgent measures to increase the release of charges to the M-13. One of these measures was to establish a tolerance for the outer diameter of the checkers equal to 1 mm.

This was formalized by the order of the plant by the head of the 3rd Main Directorate of the NKB of the USSR F.S. Ryabtsev and the head of the technical department of the same headquarters V.K. Postnikov. An increase in the tolerance to 1 mm, while maintaining all other TU requirements (including ballistic characteristics), was a turning point for a sharp increase in the release of charges. From the very next day after the approval of the new admission, all production facilities were switched to the production of charges for the M-13. It should be noted the positive role in the issue of increasing the release of charges to M-13 of the head of the military acceptance L.M. Polyakov, who proactively proposed some weakening of the requirements for those defects in the appearance of powder bills that could not have a negative effect on the ballistic qualities of charges (size superficial scratches, dents, foreign inclusions, end chips). The decision to accept charges with similar deviations from the requirements was made by the military representative on the basis of positive results of control tests of charges, in the sets of which checkers with the above deviations were uniformly introduced. The implementation of such a proposal contributed to an increase in the supply of charges for the front without compromising the quality of charges.

The work of the plant's staff during the first months of the war, which was difficult for the Motherland, was distinguished by genuine heroism. For the selfless work of organizing, in the conditions of the approaching front, the mass production of missiles for the M-13 and M-8, a group of plant employees was awarded high government awards.

It should be noted the huge role played by the South Ukrainian plant in the training of qualified personnel for the production of ballistic powder. Here is a far from complete list of the workers of this plant who made a significant contribution to the organization of the production of charges from ballistic powder at other powder factories in the country: K.I.Bazhenov, B.I. Pashkov, M.D. Gusakova, B.S.Bondar, already previously mentioned I.V. Kryzhanovsky and many others.

In October 1941, the plant was evacuated in 17 days. All the technological equipment necessary for organizing the production of gunpowder at the new location was dismantled, loaded onto platforms and wagons, and transported mainly to the Urals.

With the same echelons, engineers and technical workers and skilled workers left. All industrial buildings and structures (boiler room, water tower, communications, etc.) were blown up.

In the early autumn of 1941, in connection with the evacuation of the South Ukrainian plant, the production of missile charges for PCs in the country ceased. The front's needs for M-13 and M-8 rockets were not met, including due to the lack of rocket charges. In his memoirs relating to this period, G.K. Zhukov wrote that due to the lack of ammunition for rocket artillery, it had to be partially withdrawn to the rear / 9, p.357 /.

However, the break in the production of rocket charges did not exceed one and a half to two months. After the South Ukrainian plant was put out of action, the middle Ural plant took over the main burden of meeting the needs of the Soviet Army in missile charges for PCs of all calibers. I will dwell on his work in more detail. The site for the construction of the plant was selected back in 1930 with the participation of A.S. Bakaev. Then the design and construction of the plant began. However, at the beginning of the Great Patriotic War, the plant was not ready for the production of gunpowders, including rocket ones - an even large amount of construction and installation work had to be done.

And at the beginning of July 1941, the State Defense Committee set a combat mission for the management of the plant: during July-October to complete the first stage of the plant's construction, place on its sites the evacuated equipment necessary for the production of nitroglycerin ballistic powder and charges from them and begin their production ... This most difficult task has been accomplished.

In October 1941, the construction of the first stage of the plant was completed and in the same month the first batch of rocket charges was issued. The break in the manufacture and supply of rocket charges was eliminated / 17.18 /.

For more than a year, the Sredneuralsky plant remained the only large plant in the country that produced rocket nitroglycerin ballistic powder. The command staff played a huge role in the activities of the plant. The director was D.G. Bidinsky, chief engineer - D.E. Gorbachev, chief technologist - A.G. Kallistov. A.I. Sokolov, I.V. Kryzhanovsky, VS Bondar, D.Ya. Orlov and others.

The most difficult was the summer of 1942, when the plant was ordered to increase the production of charges for rocket and large-caliber artillery in three months several times against the originally planned. A schedule was

developed for round-the-clock construction of the second stage of the plant. The planned pace of work in the pre-war period would be considered fantastic.

The builders were just finishing laying the walls, and the installers were already installing the equipment. Additional food, footwear, clothing, and a large bonus fund were allocated.

The task of the State Defense Committee was completed in two and a half months. The country appreciated this feat. More than 1000 people were awarded orders and medals / 19, p.313-322 /.

Of great importance for the country were the work completed at the Central Ural plant during the war on the creation of a new, more productive technology for the manufacture of nyrtoglycerin powder based on the use of a system of continuous apparatus. This work began in the pre-war period. Back in November 1940, the results of preliminary tests of laboratory installations of continuous operation were considered by the NKB of the USSR and received a positive assessment / 20 /. After that, enlarged semi-plant devices were manufactured, which made it possible to carry out extensive technological research, which showed that the new technology, in addition to the incomparably higher productivity, has a number of significant advantages over the hydraulic press technology. It provided: improving the quality of gunpowder; less dangerous working conditions for service personnel; the possibility of using female labor, which was extremely important during the war; a sharp, 15-20 times decrease in the number of recurrent marriage; reduction of approximately three times the consumption of steam and electricity per ton of powder.

At the beginning of 1942, the results obtained were reviewed and approved by the Collegium of the NKB of the USSR. On its submission, the State Defense Committee adopted a Resolution of May 18, 1942 on the construction of a high-capacity production line at the Sredneuralsk plant.

On April 5, 1943, the construction of a production line based on the new technology was completed by the team of the Sredneuralsk plant. Thus, a huge amount of work in the difficult conditions of the military was completed in less than one year.

In April 1943, according to the new technology, three bulk-batching batches of charges for M-13 were manufactured, 3 thousand pieces per batch. At the same time, a special technical bureau of the plant carried out comprehensive studies of gunpowder manufactured using the new technology, primarily its ballistic characteristics. It was found that the rate of its combustion is about 9% higher than that of gunpowder made using hydraulic press technology, and therefore, in order to meet the requirements for maximum gas pressure in the engine, the calorific value of gunpowder manufactured using the new technology was reduced by 4%.

The manufactured charges were subjected to bench and firing tests over the entire range of operating temperatures.

The test results paved the way for a new technology for making charges. All work on its creation was carried out under the scientific supervision of A.S. Bakaeva, the technical manager of the development of equipment and its introduction into production was engineer A.E. Sporius. Leading engineers of the main units - F.M. Khritinin, B.A. Parfenov and others / 21; 22; 23 /.

In addition to the difficulties typical for the operation of the entire industry in the most difficult conditions of war, more than once serious technical problems specific to the production of gunpowder arose during the manufacture of gunpowders and charges. Many of these problems required a deep scientific approach and broad scientific and technical research for a correct and quick solution. A huge help to the plant in overcoming these difficulties was provided by the Special Bureau, which was transferred at the beginning of the war from the Moscow Powder Institute to the Central Urals plant.

The Special Bureau, the scientific and technical activity of which was headed by the chief engineer A.S. Bakaev, was entrusted not only with the scientific and technical support of the current production, but also with the work to improve the powders and charges, as well as to increase the productivity of the main phases of the technological process / 24 ; 25; 26 /.

I will give several examples that characterize the scientific and technical activities of the Special Bureau during the Great Patriotic War.

The issues of providing raw materials for the manufacture of nigroglycerin powder in wartime conditions became especially acute. The absence of any of the gunpowder components jeopardized the possibility of producing rocket charges. Therefore, the work on the search for substitutes, primarily centralite, was of exceptional importance. Centralite, introduced into the composition of gunpowder as a stabilizer of chemical resistance, was the most expensive and scarce component of nitroglycerin powder even before the war, which was explained by the complexity of manufacturing both itself and the main raw material for it.

After the evacuation of the Dorogomilovsky chemical plant from Moscow, the only centralite producer at that time, its production in the country was discontinued. In mid-1942, centralite reserves at the Sredneuralsk plant were running out. The production of PC charges was about to stop. However, a solution was found. Due to the absence of centralite, the idea arose to introduce magnesium oxide, which is a weak base, as a stabilizer for the chemical resistance of gunpowder. This gunpowder, named NM-2, was used to manufacture experimental batches of charges for the M-8 and M-13.

Extensive bench tests, as well as control shooting tests carried out at the range, passed with positive results. During these tests, it was found that if the charges made from gunpowder H did not always work normally at temperatures of minus 30 ° C and below, then charges made of gunpowder containing magnesium oxide worked steadily in the entire range of possible temperatures for the combat use of the RS, giving simultaneously lower pressure level at maximum positive charge temperature.

It turned out that magnesium oxide, introduced only as a stabilizer for the chemical resistance of gunpowder, significantly improved its ballistic qualities. The work of the Special Bureau in this direction laid the foundation for studies of catalytic processes in the combustion of propellants, the search for the most effective combustion catalysts, etc.

On September 7, 1942, due to the complete depletion of the centralite reserves, gunpowder with magnesium oxide was put into production. It took the plant only three days to set up its implementation and move on to mass production of charges. For four months (until January 1, 1943), the Sredneuralsk plant produced more than 3000 tons of NM-2 gunpowder for M-13 and M-8. It is impossible to overestimate the importance of these works to ensure a continuous supply of charges for the needs of the front.

One more example. In February 1942, the gunpowder factory was threatened with a complete shutdown due to the lack of Vaseline. A special bureau, as a result of intensive research, proposed replacing petroleum jelly with less scarce transformer oil. The experiments carried out confirmed not only the possibility, but also the expediency of such a replacement, since it is much more convenient to introduce liquid transformer oil into the powder mass than thick and viscous petrolatum. The plant shutdown was prevented.

The special bureau carried out other work aimed at eliminating interference with the production of charges, of which we will mention the following. Back at the end of 1941, during bench tests of a number of charges for M-13 and M-8, gas pressure in rocket chambers was obtained, the level of which exceeded the requirements of technical documentation, and in terms of chemical composition and other indicators, the batch of charges met the requirements of TU. Acceptance of missile charges was suspended. In this regard, the employees of the Special Bureau carried out a detailed study of the reasons for the substandardness of the charges manufactured by the plant and revealed the important effect of the caloric content of the powder mass on their ballistic characteristics.

The result of the work was the establishment and introduction into the technical documentation of the norms for the caloric content of gunpowder, as well as the development and introduction into production of the specified dosage of gunpowder components when cooking the powder mass.

At the same time, the conditions for rolling and pressing of gunpowder were improved. The implementation of these measures ensured, since January 1942, a stable production of charges that fully meet the requirements of the documentation.

Substantial assistance from the Special Bureau was provided to the plant to find out the reasons for the marriage resulting from the pressing of powder bills on Krupp presses. So, for example, in February 1942, the scrap in the phase of pressing charges M-8 and M-13 averaged 30-35%, reaching 55-60% on some days. The team of the Special Bureau carefully analyzed the reasons for the marriage and gave precise and specific recommendations. At present, there is no need to list all the recommendations, but one cannot but give a high assessment of the methodological side of the Special Bureau's work, the seriousness of the approach to finding the causes of difficulties, the persuasiveness and evidence of recommendations. Suffice it to say that after the development of the recommendations, the next production of charges around the clock in all shifts was carried out under the direct and continuous control of the employees of the Special Bureau.

By the end of 1944, the volume of the plant's production increased tenfold compared to 1942, and although by that time other gunpowder factories built during this time were already working at full capacity, the pace of work of the Middle Ural plant was constantly increasing.

During the battle for Moscow in 1941, the 562 plant, created in November 1941 on the basis of the Moscow Powder Institute, was the closest supplier of rocket charges to M-13 and M-8 rockets.

The workshop for the production of rocket charges at this plant had two Krupp hydraulic presses and other necessary equipment. The workshop was headed by an experienced engineer VS Dernov, who in the pre-war period was directly involved in the development of rocket charges and their introduction into production at factories.

Thanks to the selfless work of the staff of the 562 plant during the fierce battles for Moscow, the supply of PC charges by this plant was sharply increased.

An important role in the supply of missile charges to the PC, intended for the units of the Soviet Army that participated in the defense of Moscow, as well as the subsequent period, was played by the 512 plant, created in one of the villages near Moscow at the end of 1941.

Plant 512 received part of the equipment evacuated from the South Ukrainian plant: two Krupp hydraulic presses, two Verne-Pfteider presses, four calibration rolls and four cutting machines. To organize the production of gunpowder and charges, experienced powderguns from other factories, as well as young specialists (S.A. Mekalina, V.O. Morozov, Ya.P. Mironov, V.I. Tikhonov, N.I. Tikhonova, N.I. K. Volovinskaya and others).

The development of the production of charges was seriously delayed by a major accident on February 11, 1942 during the pressing phase. Krupp's press was disabled. Not without human sacrifice. However, already in March 1942, the production of charges began, initially mortar charges. The plant began production of rocket charges in May 1942 with the production of charges for M-13 by altering the substandard artillery nitroglycerin powder brought to the plant. In the following months of 1942, the manufacture and delivery of rocket charges went on in an increasing flow. The importance of these supplies was especially great, since the time from the delivery of the charges to their arrival at the assembly bases, and then at the military units, was minimal - after the stabilization of the front near Moscow in April 1942, the distance from the 512 plant to the positions of the Soviet troops in this area did not exceed 120 km.

In parallel with the release of charges from imported remake powder, the 512 plant created the necessary production base for the complex manufacture of gunpowders. So, at the beginning of 1943, the construction of the nitro unit was completed. On March 3, the first nitration of glycerin was carried out, and on March 25, the nitro unit was accepted by the Commission of the NKB of the USSR into permanent operation. The creation of its own production base allowed the plant to dramatically increase the production of rocket charges, including for the M-31 rocket projectile, developed during the war and put into service in March 1943. Already in April 1943, the plant manufactured the first batch of charges for this projectile - 4300 sets.

Of great importance for increasing the efficiency of the plant's work was the transfer in July 1943 to the plant 512 of the Special Bureau, which was previously located at the Central Urals gunpowder plant. A.S. Bakaev was the chief engineer of the Special Bureau. Somewhat later, he was transferred to the position of chief engineer of plant 512.

The volume of the plant's production increased especially in 1944. One of the important prerequisites for this was the continued expansion of the plant's production base. The powder mass brewing workshop, having received new equipment manufactured at the Sredneuralsk plant, switched to a new progressive semi-continuous method for the production of powder mass.

In February 1944, the construction of the test base was completed, which sharply reduced the time spent on acceptance bench tests of charges, which were previously carried out at the stands of other enterprises. The first test of rocket charges at its base was carried out on October 20, 1944.

In May 1944, the plant's central laboratory was commissioned. Since then, the results of the analyzes carried out by it have become official and have begun to be entered into the forms for the manufactured products. Until May 1944, all the necessary analyzes of gunpowders were carried out by the Moscow Gunpowder Institute, which inevitably lengthened the delivery time of the finished product.

As a result, the production of gunpowders in 1944 almost doubled the production in 1943. In 1945, the plans for the production of rocket charges at the 512 plant were reduced. The reason for this was the full deployment in 1944 of the production of rocket charges at a number of powerful powder factories in the east of the country.

In total, over the years of the Great Patriotic War, the 512 plant produced about 550 thousand rocket charges, including about 217 thousand for M-13 projectiles and about 308 thousand for M-13 [*So in the text. probably meant M-13 and M-8 - im*]. All the charges supplied were of exceptionally high quality. The plant did not have a single complaint from the troops during the entire period of the Great Patriotic War.

In 1945, after the end of the Great Patriotic War, plant 512 as a gross plant for the production of gunpowders and charges from them ceased to exist and was transformed into a research institute. [*NII-125, Dzerzhinsky, Moscow Region, MAP (1947), IOM (1965), later Scientific Research Institute of Chemical Technology - im*]

In total, during the Great Patriotic War, the country's gunpowder industry supplied more than 14 million rocket charges to the Army. Particularly great was the contribution of the Middle Urals plant, which produced about 2/3 of the total production of charges. About 16% of the charges were manufactured by the North Ural plant, which launched its work on the production of rocket charges in the second half of 1942. About 10% of the charges were made by the South Ural plant, which produced the first batches of charges for M-13 and M-8 on February 23, 1943. Rocket powder and charges ceased to be a bottleneck in meeting the needs of the front with rockets of all calibers.

Rocket charges from pyroxylin powder for rockets M-13 and M-8

In the first months of the Great Patriotic War, especially after the South Ukrainian plant was put out of action, the country's gunpowder industry, which produced ballistic powder, could not ensure the supply of charges to complete the M-13 and M-8 missiles in the required quantities. Meanwhile, the need for charges was not only enormous, but also increased.

The gunpowder industry was faced with the task of organizing the production of rocket charges for M-13 and M-8 rockets at the country's pyroxylinic powder factories and thereby ensuring the supply of the front with rockets before the new plants for the production of nitroglycerine ballistic powder are put into operation. Work on the creation of rocket pyroxylin powder was carried out by the Special Technical Bureau (OTB) of the Volga plant of pyroxylin powder / 27; 28 /.

Initially, we took the path that, if successful, would allow in the shortest possible time to organize the production of charges, namely, along the path of developing rocket charges for M-13 and M-8 from standard pyroxylin powder.

However, these attempts ended in failure. The tests carried out in August-October 1941 of charges made of pyroxylin powder of standard composition, made by the usual technology of pyroxylin powder, showed that at a low temperature of the charges, their combustion was unstable, accompanied either by damping or irregular increases in pressure in rocket chambers M-8 and M-13.

It was necessary to concentrate efforts primarily on the development of new compositions of pyroxylinic propellants. The task was hampered by the fact that, at the request of the developers of the projectiles, the diameters of the critical sections of the rocket engine nozzles (19 mm for the M-8 and 37.5 mm for the M-13) should have remained unchanged when switching to charges from new propellants. This requirement, although it greatly complicated the work of the creators of propellants and charges, was accepted by the powder makers for mandatory execution as one of the main requirements.

Indeed, only when it was carried out was complete interchangeability of rocket charges made of pyroxylin and standard ballistic powders ensured. The interchangeability of the charges not only simplified the work in organizing the production of rocket engines at a multitude of mechanical factories involved for this purpose, but also ensured the correct completion of M-8 and M-13 rockets with charges in any of the most unexpected situations that could arise in complex and not always controlled conditions of wartime, which in the end was one of the conditions ensuring the safety of the use of missiles during their combat use.

In December 1941, OTB had already developed a powder recipe that could be used to make charges for PC M-13 and M-8. The gunpowder was named PS, which meant pyroxylin-nitrate. The mass composition of this powder is given below in%:

pyroxylin - 68 ± 2;
potassium nitrate - 20.6 ± 2;
rosin - - 2.2 ± 0.3;
diphenylamine - 1.0 ± 0.3;
volatile (alcohol, ether, water) - 7.5-9.0.

The density of the powder was 1.58 g / cm ^{3} , and the calorific value (heat of combustion) was (745 ± 15) kcal / kg.

Rosin was introduced into the powder as a phlegmatizer in order to reduce the combustion rate of the powder to a level that allows its use in PC M-8 and M-13 chambers without changing the nozzle throat diameters, diphenylamine was introduced to provide the required chemical resistance of the powder.

The gunpowder met the main requirement for that period: it could be manufactured on the existing equipment of the pyroxylin powder plants. The duration of the technological cycle was 13-14 days.

The charges for M-13 and M-8 were designed from pyroxylin nitrate powder. The design of the missile charge developed for the M-13 is shown in Fig. 10. To reduce the duration of the process of removing the solvent from the powder cartridge for the M-13 projectile, it was necessary to minimize the thickness of the burning dome of the powder cartridge as much as possible. This problem was solved by creating a three-petal checker with three channels with a diameter of about 5 mm and a thickness of the burning arch of about 8 mm.

The rocket charge was completed with eight blocks of 500 mm length and ensured the normal operation of the rocket engine without changing the critical section of the nozzle and other engine elements. The mass of the charge was set at 6000 ± 50 g instead of 7050 ± 35 g for the gunpowder H charge, i.e. 15% less than the mass of the standard charge.

The decrease in the mass of the charge made of pyroxylin-nitrate powder in comparison with the mass set for charges made from standard ballistite powders was due to the fact that when determining the described diameter of a checker from gunpowder PS, one had to take into account the fact that when removing a volatile solvent from pyroxylin powder, the straightness of the pressed checkers violated. A rather significant curvature appeared. In order to ensure the unconditional entry of the powder charge into the rocket chamber at assembly bases, it was necessary to artificially underestimate the described diameter of the powder bills in comparison with the theoretically possible. This reduced the lateral filling of the rocket chamber, and hence the mass of the charge.

Since the specific impulse of the reactive force of gunpowder PS was also less than that of ballistic powder N, the range of the M-13 projectile with a charge of PS gunpowder was 25-30% less than the flight range of the M-13 projectile with a charge of N gunpowder.

When designing a rocket charge for the M-8, it was proceeded from the fact that a decrease in the range of the M-8 projectile by another 25-30% when switching to PS pyroxylin nitrate powder was extremely undesirable. In order to maintain the range of the M-8 projectile, it was decided to lengthen the rocket chamber, thereby increasing the mass of the charge, and thus compensate for the loss of the full impulse of reactive force when switching to gunpowder PS.

A rocket charge was designed, which consisted of seven single-channel cylindrical blocks with an outer diameter of 23.5 mm and a channel diameter of 5 mm with a block length of 287 mm (Fig. 11). The mass of the charge was 1175 ± 10 g instead of 1040 ± 10 g for the charge made of gunpowder N before its modernization. As a result of the work carried out, the flight range of the M-8 projectile did not change after switching to gunpowder. This was a major achievement of OTB of the Volga plant.

The work on the creation of pyroxylin-nitrate propellants and charges from them was carried out at the OTB under the leadership of N.P. Putimtsev. IM Silaev, OP Mikhailusov, VV Shnegas, FN Poida and others took part in the work. The production of rocket charges from pyroxylin-nitrate powder, in addition to the Volga plant, was also organized at one of the Siberian plants.

Pyroxylin-nitrate gunpowder PS, which made it possible to use the capacity of pyroxylin powder plants and bridge the gap between the production of hulls for rockets and propellant charges for them, undoubtedly played a positive role in 1942, because allowed the Red Army to use rockets M-8 and M-13 on a fairly large scale. However, PS pyroxylin nitrate powder had serious drawbacks, the main one of which was the observed rupture of rocket chambers during firing in some cases (one case in 300).

The latter circumstance led to the fact that only in 1942 every fourth batch of charges (18 out of 68) was returned from the Army to the Siberian plant that produced these gunpowders. In order to strengthen control over the quality of the manufacture of charges, acceptance bench tests were introduced in an expanded scope (50 experiments instead of 7).

At the same time, new technical specifications for the charge were developed, in which the requirements for sorting out powder bills by their appearance were much stricter. However, the experience of the factories with the new technical specifications showed that no improvement occurred. So, for example, in bench tests of charges from gunpowder PS for every 60 shots in one case, the gas pressure in the rocket chamber exceeded the established norm. At the same time, the outward appearance of the gunpowder did not have any external signs by which it would be possible to separate the good from the substandard. Thus, the accepted method of production of gunpowder PS and very strict methods of sorting out in appearance did not guarantee the receipt of rocket checkers of satisfactory quality. The reasons for this phenomenon were thoroughly investigated by the staff of the Moscow Powder Institute G.K. Klimenko, A.N. Gukasov and others / 29 /. They proved that the main and determining factor leading to a violation of the combustion stability of PS powder is its structural heterogeneity due to the presence of inorganic solid inclusions (nitrate) in it and the presence of cracks, bubbles,

ungelatinized pyroxylin, etc. With unfavorable combinations of these factors, the combustion surface area could increase by 4-5 times, which inevitably led to a sharp increase in pressure in the engine, to its possible destruction.

Starting in 1943, the country's gunpowder industry was already able to meet the needs of the front by supplying rocket charges only from nitroglycerin ballistic powder, and the need to manufacture charges from pyroxylinic gunpowders disappeared. Their production was discontinued.

On the state of Germany's jet armament

It is of great interest to assess the missile armament of Germany - our enemy during the Great Patriotic War.

The most complete answer to this question is given by the report of the Commission for the Study of German Jet Armament, published in September 1946 and approved by the Main Directorate of Armaments, Guards Mortar Units / 30 /. This commission (chaired by General A.I. Sokolov) was sent to Germany immediately after the end of the war and conducted a deep study of all materials that came into its possession.

In its report, the commission noted that in Germany in the pre-war and war years, 64 nomenclatures of rockets of various classes were developed, including:

Field Artillery PC - 13
Aircraft PCs and bombs - 16
Anti-aircraft PC - 11
PC for the Navy - 8
Anti-tank PC - 5.

However, as you know, the use of missile weapons by the Germans was of a very limited scale, which cannot be compared with the massive and very effective use of MLRS by our troops. What's the matter? To answer this question, we will involve the materials of the Academy of Artillery Sciences / 31 /.

In March 1948, at a meeting of the 3rd branch of this Academy, A.S. Bakaev's report on the state of Germany's jet armament and the reasons for its limited use during the war with the USSR was heard. In this report, a table was given with data on the production of gunpowder in Germany. Let's reproduce it (Table 5).

Table 5.

Gunpowder production in Germany

Years	Produced in total per year, tons	No volatile solvent	Pyroxylin powder	Percentage of propellants without volatile solvent
1914	14615	6285	8330	43
1916 *	74300	35427	38873	47
1917	93751	46881	46880	fifty
1918	100488	59172	41316	58
1939	13728	7740	5988	56
1943	246036	205764	40272	85
1944	268944	232512	36437	87

* The maximum production of gunpowder in Russia at all factories in 1916 was approximately 15 thousand tons (only pyroxylin and black powder). The missing gunpowder Russia imported from France, England, Japan.

From this table it follows that already during the war years 1914-1918. In Germany, not only were the formulations of ballistic-type propellants suitable for creating rocket charges were known, but there was also sufficient industrial capacity for their production. This means that already in those years, German military designers had, in principle, the capabilities for the development of effective jet weapons and their mass production. However, these opportunities were not used by them at that time.

These possibilities were not used in Germany even later, when in 1929 the work on the creation of weapons using the reactive principle was revived. The development of rocket charges was carried out, as in the 19th

century, on smoky (black) powder, which, like rocket fuel, had a number of drawbacks (low technology, fragility, low energy).

A.S. Bakaev, in his report mentioned above, said: “Oddly enough at first glance, but despite the prevailing importance in Germany of those propellants that are best suited as solid fuel for jet engines, the Germans used these propellants for PC later than the USSR ".

Indeed, the first experiments on replacing black powder in jet engines with ballistic powder, namely dinitrodiethylene glycol, began in Germany only in 1935-36.

And then A.S. Bakaev noted: "During the war, having experienced the effectiveness of the massive use of rocket artillery by the Red Army, the Germans began to develop this new (more precisely, reborn) type of weapon at a feverish pace" / 31 /.

By the end of the war, 9 factories, 13 research institutes, as well as the largest company Rheinmetall-Borzig / 31 / were engaged in rocketry in Germany and occupied Czechoslovakia.

However, a huge obstacle in the way of arming the German army with new powder PCs was the impossibility for the German powder industry, based on the use of Krupp hydraulic presses, to prepare large-diameter and long rocket bombs on a mass scale. To solve this problem, the Germans took the path of increasing the power, and, consequently, the size of the hydraulic presses, which was an undoubted mistake. Working in this direction, they reached the manufacture of giant "mammoth presses" about 14 m high and weighing up to 100 tons.

In the Soviet Union, a fundamentally different path was chosen - the creation of a continuous screw technology for the manufacture of rocket powder. This technology had not only many times greater productivity than the hydraulic press for the release of rocket charges, but also removed almost all restrictions in terms of the dimensions of the produced powder elements.

Thus, we can conclude. The decisive superiority during the Great Patriotic War of Soviet rocket armament over German is explained by two main factors:

- the use of ballistic-type propellants, which are best suited for creating rocket charges;
- development and implementation of high-performance continuous technology for the manufacture of charges, which made it possible to supply them in large quantities to the Army.

Conclusion

In 1941-1945. Soviet rocket artillery made a huge contribution to our victory in the Great Patriotic War.

The most important prerequisites for the possibility of creating rocket artillery were the development in the Soviet Union under the leadership of A.S. Bakaev in the late 20s - early 30s of domestic formulations of nitroglycerin ballistic powder for barreled artillery and the technological process of their manufacture, as well as the construction of the South Ukrainian a plant capable of producing these gunpowders in mass quantities.

The emergence in 1933 of the idea of the possibility of using nitroglycerine ballistite propellants for the manufacture of rocket charges was of paramount importance for the successful solution of the problem of creating Soviet rockets. The implementation of this idea not only brought the development of rockets out of the impasse, begun by the RNII on pyroxylinotrotyl powder, which turned out to be extremely low-tech, but also made it possible in the shortest possible time to complete the development of the RS-82 and PC-132 aviation projectiles and to adopt them for the USSR Air Force already in 1937- 1938 much earlier than it was done abroad.

The correctness of the found technical solution was further confirmed when developing from nitroglycerin ballistic powder charges for rockets M-13, M-8, M-31, etc., intended for the ground forces of the Soviet Army and created in a very short time. These charges, distinguished by their extreme simplicity of design, at that time satisfied all the requirements for ammunition and, above all, the requirements for high manufacturability of products in production and high reliability of their operation in combat use.

The most perfect charge for that time was the charge for M-13, and its calculated characteristics (loading density, intensity indicator, coefficient of mass perfection) can be considered as the starting point for assessing scientific and technological progress in the field of solid fuel rocketry.

The principle of unification of missile charges, implemented during the Great Patriotic War, was extremely important for the fastest creation of rockets for various purposes, thanks to which, on the basis of one design of a rocket charge, a whole range of rockets was created in the shortest time (M-13, M-20, M -30, M-13DTS, M-13UK). This principle has not lost its significance at the present time.

Delays at the beginning of the war in the supply of missile charges associated with the evacuation of the South Ukrainian plant in October 1941 were eliminated by the gunpowder industry in a minimum amount of time by creating new powder production facilities in the east and center of the country.

The implementation of all the plans for the release of missile charges that grew during the war was facilitated by the prompt decision by scientists and designers of the Special Bureau of the Sredneuralsk plant and engineers of factories that produced gunpowder, scientific and technical problems that arose during the mass production of charges and more than once threatened a complete stop of production.

So, instead of the scarce components of propellants (petroleum jelly, centralite), their full-fledged substitutes were found and their rapid introduction into production was ensured. Of particular importance was the implementation, under the leadership of A.S. Bakaev, of a set of measures to increase the volume of production and, above all, the completion of the development and creation at the Sredneuralsk plant of a new continuous high-performance technological process of manufacturing charges.

All of the above allowed the Soviet troops to use jet weapons on a mass scale with the highest efficiency during the Great Patriotic War. The salvos of victorious Soviet rocket artillery that thundered on all fronts of the Great Patriotic War were also salutes to the heroic work of scientists, engineers and workers in the powder industry of the Soviet Union, who had fulfilled their duty to the Motherland.

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